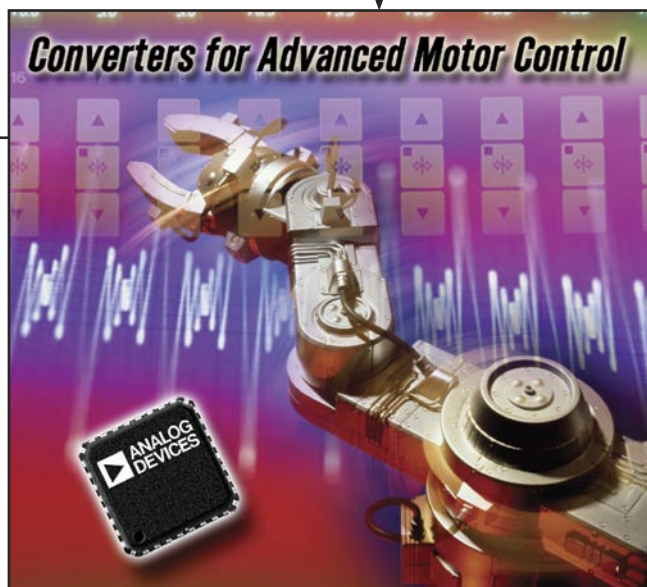


Converters for Motor Control

Higher performance, greater accuracy and speed, and ultralow power consumption highlight Analog Devices' portfolio of data converters for motor control. Each delivers optimum quality signals to/from the real world and processes the data with less development time, fewer parts, and lower costs.



Analog Devices converters for motor control solve challenges associated with current and voltage monitoring, optical encoder feedback, and resolver-to-digital conversion. These processes are vital to industrial applications, such as assembly-line robots, and also to automotive applications, such as power-assisted steering, both of which require precise control of motor speed and mechanical movements. The new converters feature some of ADI's best-in-class technologies and include the following:

- AD7266—The industry's fastest 12-bit, simultaneous sampling, successive approximation register (SAR) analog-to-digital converter (ADC), featuring 2 MSPS throughput per channel and less than half the power consumption of competitors
- AD7400—The industry's highest performance, isolated, Σ - Δ ADC, incorporating ADI's award-winning iCoupler® digital isolation technology, which enables higher speed and accuracy at lower power
- AD2S1200—A completely monolithic resolver-to-digital converter (RDC), offering the best combination of speed, accuracy, and functionality in a space-saving design
- AD7656—World's first 6-channel simultaneous sampling ADCs with true bipolar input ranges of ± 5 V and ± 10 V with twice the accuracy of comparable devices
- ADuC7000 Series—Precision analog microcontrollers with high performance A/D and D/A combined with the ARM7® Core

Converters for Advanced Motor Control

Precision motor control is needed in multiple application areas including industrial automation, HVAC, automotive, appliances, consumer products, medical equipment, aerospace and semiconductor manufacturing. Almost all high volume manufacturing processes depend on automated assembly lines and robots for precise and consistent production flows. Other applications include milling machines and lathes for precision tooling. Typically, systems require the movement of a load from A to B as quickly and precisely as possible. This load can be variable or constant requiring fast and precise digital feedback for optimum control of motor currents and torque.

The emergence of high speed digital processors and modern converters has enabled the use of closed-loop control in contrast to open-loop control. Consequently, one of today's trends is to replace the open-loop stepper motors with closed-loop servos. Such systems have increased reliability and repeatability. They are less susceptible to noise and drift with temperature and time. They are also easier to communicate with.

ADI provides a choice of converters, including standard, isolated, and resolver-to-digital, to slot into motor controllers as shown in Figure 1. Current monitoring in the torque loop has to be high voltage tolerant with respect to each phase and with respect to the controlling circuitry. Regulated safety standards from UL, CSA, and VDE require up to 3.75 kV of reinforced isolation such as those specified with the current sensing AD7400 ADC. Servo drives have shaft position feedback used for precise control such as spot welders on assembly lines and milling machines. This additional feedback is typically

based on either a sin/cos optical encoder or a resolver. The AD7266 dual simultaneous sampling ADC front end is optimized to interface with popular encoders with a minimum of support circuitry while the AD2S1200 provides an integrated resolver-to-digital solution. The AD7656, 6-channel ADC is popular for either current control or shaft position feedback in multi-axis feedback loops. The ADuC7000 series of precision analog microcontrollers has multiple ADCs and DACs, 32-bit RISC machines, and peripherals for motor controller applications.

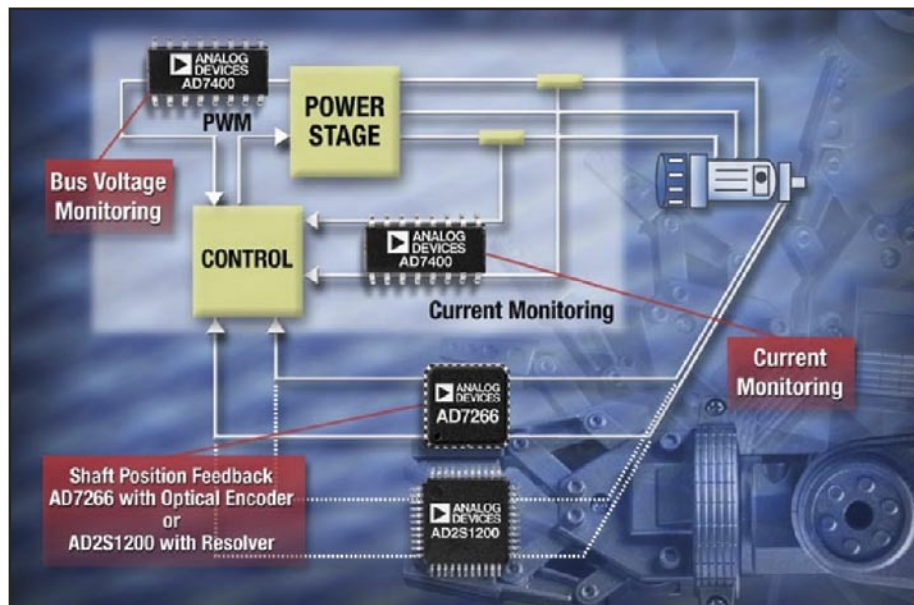


Figure 1.

AD7266—12-Bit, 2 MSPS Simultaneous Sampling, 3-Channel ADC Stands Above All Others

The AD7266 dual, 3-channel, 12-bit ADC outdistances the competition (as illustrated in Figure 2), providing advanced functions and features that allow designers to optimize their industrial applications to a whole new level. Each ADC operates at 2 MSPS. And, with twelve AIN inputs (driven with single-ended inputs or six differentially), the AD7266 can interface directly with optical encoders, eliminating the need for external components while simplifying your design and lowering overall cost. Add in the industry's best accuracy and power specs, along with a competitive price, and you've got a part that is unequalled. For lower speed applications, we also offer the AD7265, which operates at 1 MSPS.

Features

- Dual, 12-bit, 3-channel, differential I/O ADC
- 2 MSPS per ADC (AD7266)
- 1 MSPS per ADC (AD7265)
- Specified for V_{DD} of 2.7 V to 5.25 V
- Low Power:
 - 9 mW max at 1.5 MSPS with 3 V supplies
 - 27 mW max at 2 MSPS with 5 V supplies
- Wide input bandwidth
- 70 dB SINAD at 50 kHz input frequency
- On-chip reference: 2.5 V
- -40°C to $+125^{\circ}\text{C}$ operation
- 32-lead LFCSP

Applications

- Multiaxis positioning systems
- 3-phase current control
- Data acquisition systems
- Uninterrupted power supplies
- Multiphase motor control
- Industrial control
- Telecommunications
- Automotive radar

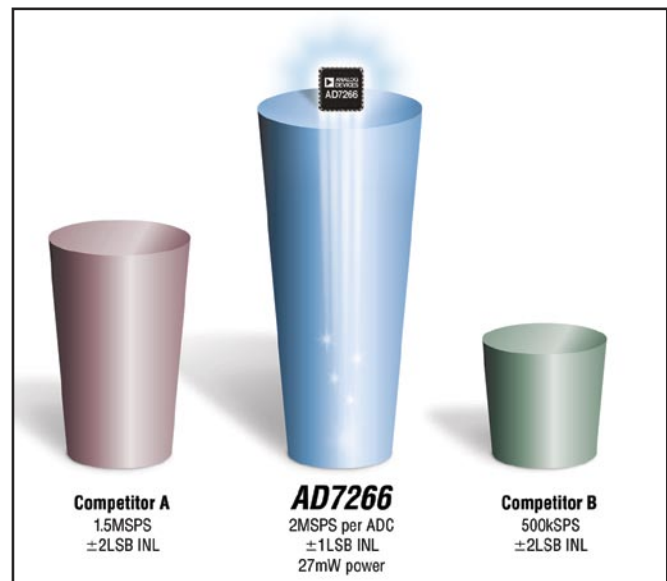


Figure 2. AD7266 competitive performance comparison.

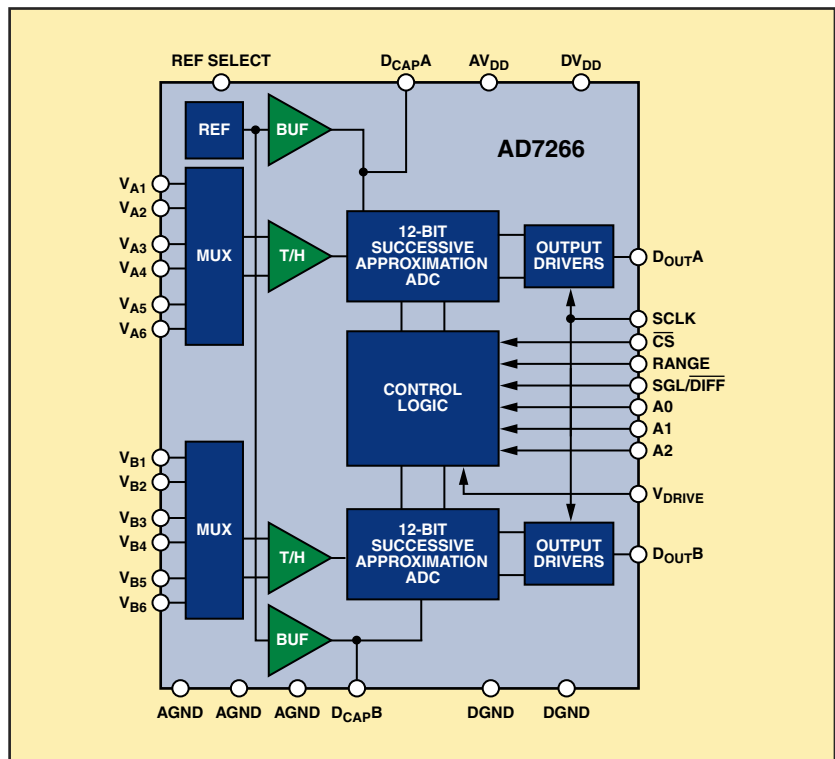


Figure 3. AD7266 functional block diagram.

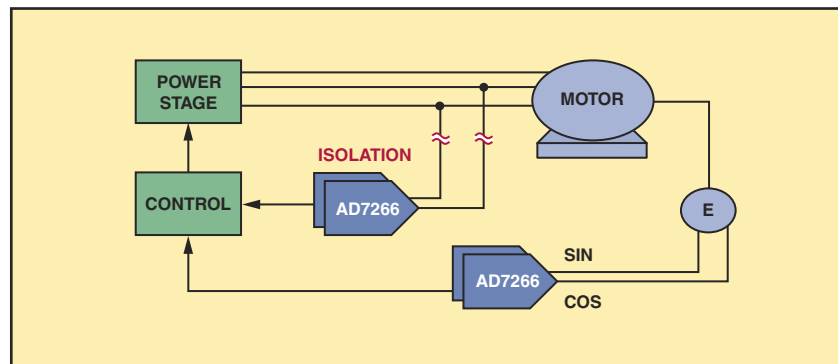


Figure 4. The AD7266 controls phase currents and also phase relationships in encoder sin/cos outputs.

AD7400/AD7401—Isolated Σ - Δ ADCs Enable Extreme Accuracy in Current Monitoring

ADI has combined their advanced Σ - Δ expertise along with their *iCoupler*® isolation technology to create a high performance isolated ADC. The AD7400 has 6 $\times$ better accuracy and half the drift of the nearest competitor. Inputs are optimized for current monitoring across shunt resistors and provide more than 3.75 kV of isolation across the communications port.

ADI has created high performance isolated ADCs by bringing together their *iCoupler* isolation technology and industry-leading, Σ - Δ modulators. The AD7400 and AD7401 provide the ideal isolated Σ - Δ solution, providing 13-bit linearity and sample rates up to 10 MSPS. They are popular choices for current monitoring applications. The integration of our *iCoupler* technology allows for isolated, high speed data rates with low power. The ADC inputs are optimized for monitoring current through shunt resistors, while protecting the digital communication lines with a 3.75 kV reinforced isolation barrier. The converter operates from a 5 V power supply and accepts a ± 200 mV signal range, making it suitable for direct connection to current shunts. The converter's offset drift of 5 μ V/°C is half that of competitive solutions.

Two versions are available: the AD7400 features an internal clock to minimize external components, and the AD7401 uses an external clock to synchronize multiple converters.

Motor Speed vs. Torque Response Measurement with AD7400

Tests on a servo drive system which used the AD7400 in the current feedback loop showed fast loop-settling times as the motor was run in acceleration/deceleration cycles. Ideally, the response will exhibit a small overshoot in speed with no oscillations as shown in the plot in Figure 5. Both speed and current are ripple-free.

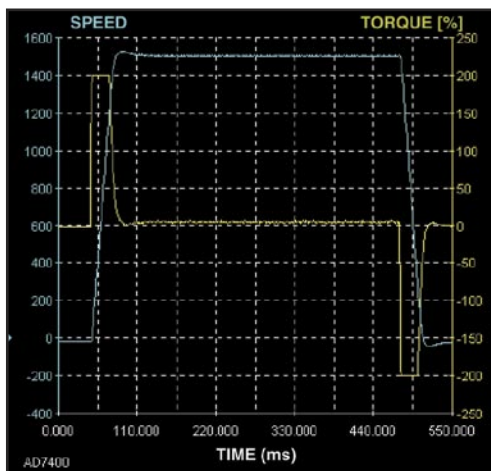
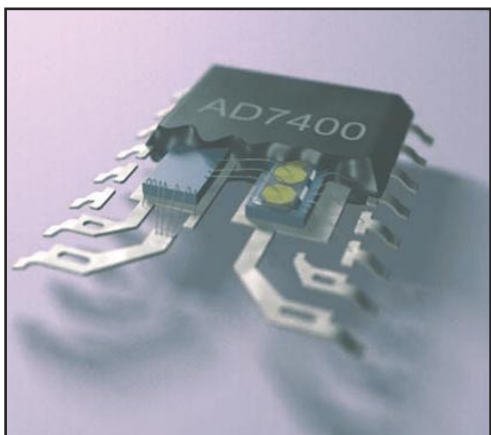


Figure 5.



AD7400/AD7401 assembly view.

Features

- AD7400—10 MHz data rate (internal clock)
- AD7401—18 MHz data rate (external clock)
- 2nd-order modulator
- ± 10 LSB max linearity in 16 bits
- On-chip digital isolator
- On-chip reference
- ± 200 mV AIN range
- Low power operation:
 V_{DD1} : 12 mA max @ 5 V
 V_{DD2} : 3 mA max @ 3 V
- -40°C to $+105^{\circ}\text{C}$ operating temperature range
- 16-lead SOIC package

Applications

- AC motor control
- Isolated data acquisition systems
- A/D + optoisolator replacement

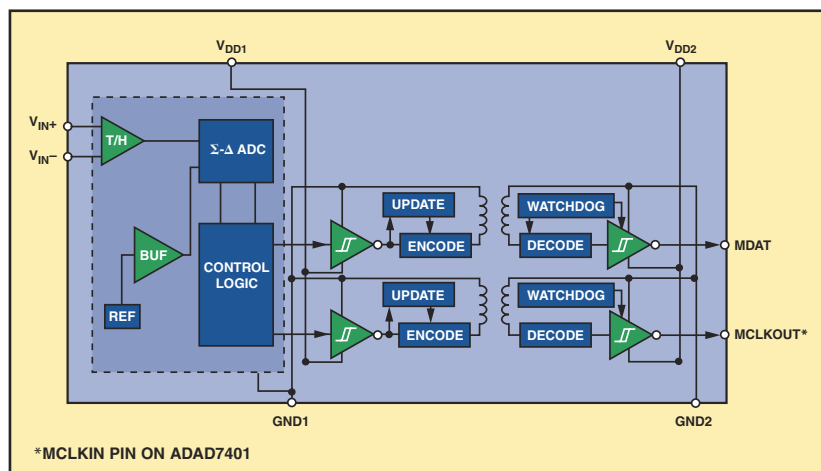


Figure 6. AD7400 block diagram.

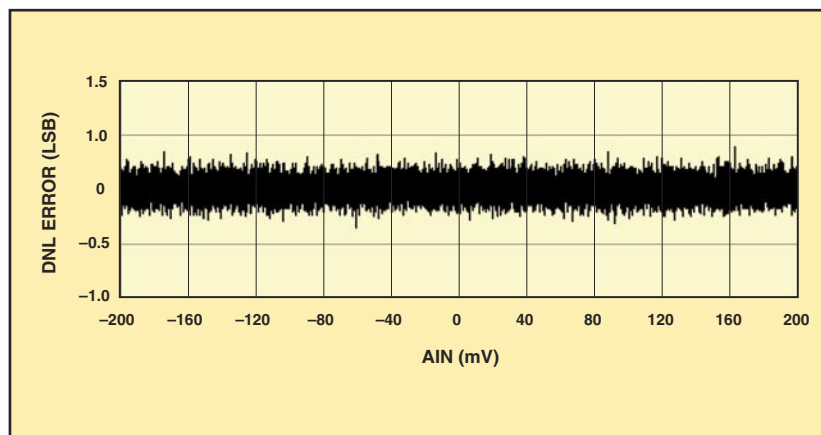


Figure 7. AD7400 16-bit DNL plot.

Features

- Complete monolithic R/D converter
- Parallel and serial 12-bit data ports
- System fault detection
- Absolute position and velocity outputs
- Differential inputs
- ± 11 arc minutes of accuracy
- 1,000 rps maximum tracking rate, 12-bit resolution
- Incremental encoder emulation (1,024 pulses/rev)
- Programmable sinusoidal oscillator on-board
- Compatible with DSP and SPI® interface standards
- 204.8 kHz square wave output
- Single-supply operation (5.00 V $\pm 5\%$)
- 44-lead LQFP package



Figure 8.

Where to go for more info:

Analog Devices home page
www.analog.com

Motor Control home page
www.analog.com/motorcontrol

Samples
www.analog.com/samples

Signal Chains
www.analog.com/signalchains

Technical Online Seminars
www.analog.com/online seminars

AD2S1200—Space-Saving RDC Solution Delivers Robust Performance and Functionality

A complete monolithic resolver-to-digital converter, the AD2S1200 equips designers with a fast (up to 1,000 rps), accurate (up to ± 11 arc minutes), fully integrated RDC solution. The converter contains a 12-bit resolution tracking loop and an on-board programmable sinusoidal oscillator that provides sine wave excitation. Other key features include a fault detection circuit that detects any loss of resolver signals, out-of-range input signals, input signal mismatch, or loss of position tracking. The chip communicates via a 12-bit parallel port or 3-wire serial interface. The resolver also provides an incremental encoder emulation output with 1,024 pulses per revolution with additional directional pulse, eliminating the need for external A and B directional decode logic. The device operates from a single 5 V supply over a temperature range of -40°C to $+125^{\circ}\text{C}$.

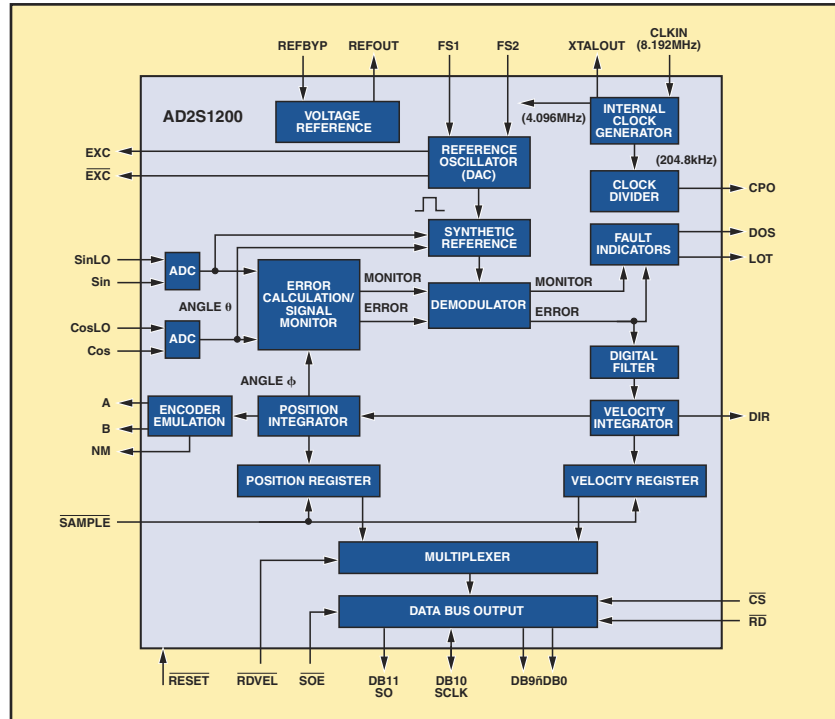


Figure 9. AD2S1200 functional block diagram.

In addition to the world's leading portfolio of data converters, Analog Devices features higher performing, highly innovative solutions for every step in the industrial signal chain.

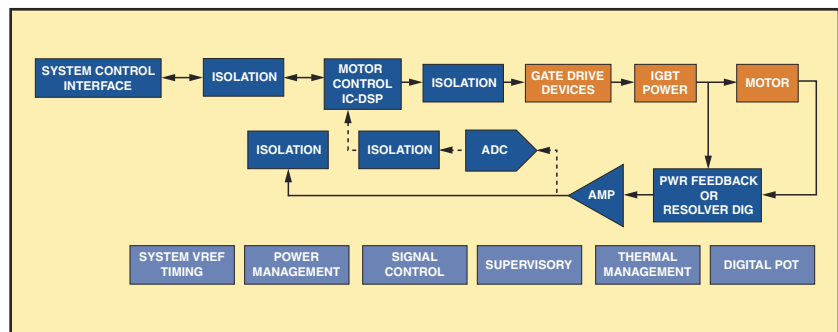


Figure 10. Typical motor control signal chain.

AD7656—World's First 6-Channel Simultaneous Sampling ADCs with True Bipolar Input Ranges of ± 5 V, ± 10 V, Has Twice the Accuracy of Comparable Devices

The AD7656 16-bit ADC offers simultaneous sampling on six channels and twice the accuracy of comparable devices (± 4 LSB max INL) at 250 kSPS per channel.

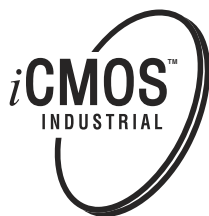
The AD7656's 16-bit resolution and simultaneous sampling capability make it an ideal choice for power line monitoring, motor control, instrumentation, and multiaxis positioning systems that require high precision ± 10 V signal ranges and multichannel simultaneous sampling capability. The AD7656 is highly integrated, with six 16-bit successive approximation ADCs offering 4 LSB max INL and fast throughput rates (250 kSPS per channel)—plus a 2.5 V internal reference and reference buffers—all housed in one package. At 160 mW, the part also enables a 60% reduction in power consumption compared to the closest comparable ADC.

The AD7656 contains low noise, wide bandwidth track-and-hold amplifiers that can handle input frequencies up to 8 MHz. The three ADC pairs can be independently, simultaneously sampled. The AD7656 has high speed parallel and serial interfaces, allowing the device to interface with microprocessors or DSPs. When in serial interface mode, the AD7656 has a daisy-chain feature that allows multiple ADCs to connect to a single serial interface. The pin-compatible AD7657 and AD7658 offer the same features as the AD7656, but at 14-bit and 12-bit resolutions, respectively.



Figure 11. AD7656 DNL plot.

Generic	Resolution	Speed	Package
AD7656	16	250 kSPS	64-lead LQFP
AD7657	14	250 kSPS	64-lead LQFP
AD7658	12	250 kSPS	64-lead LQFP



The ADCs—designed on Analog Devices' iCMOS industrial process technology—were developed to meet the industrial sector's growing demand for higher resolution and channel counts, faster conversion times, and lower power consumption.

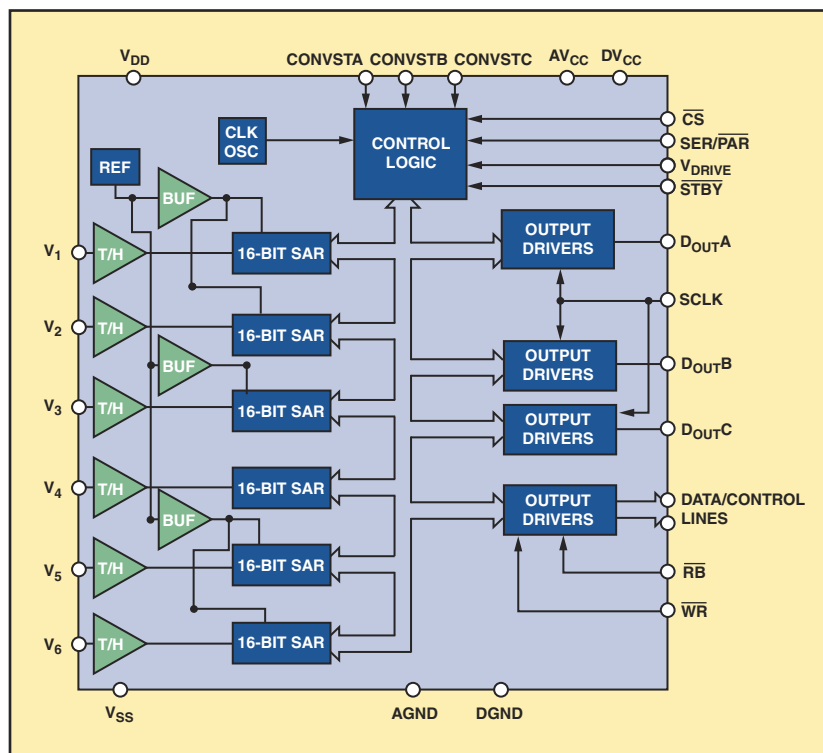


Figure 12. AD7656 functional block diagram.

Key Features

- ARM7 TDMI MCU core
- 16-bit/32-bit RISC architecture, 44 MHz operation (Flash/EE and SRAM)
- Embedded JTAG for debug

Memory Organization

- 8 kB SRAM in $2k \times 32$ bits
- Up to 128 kB Flash/EE in two blocks of $31k \times 16$ bits
- Retention: 20 years
- Endurance: >10 kcycles
- In-system programming (ISP) via UART or JTAG ports

Analog I/O

- Multichannel, 12-bit, 1 MHz ADC
- Multiple 12-bit V-output DACs
- 10 ppm/°C V_{REF} , 3°C temperature sensor
- Uncommitted comparator

Others

- 4 × GP timers
- Programmable logic array (PLA)
- UART, SPI, dual I²C[®] serial I/O
- Up to 40 GPIO pins
- Power supply monitor
- 3-phase PWM
- Specified for 3 V operation (5 V-compatible I/O)
- Temperature range: -40°C to +125°C
- 6 mm × 6 mm and 9 mm × 9 mm LFCSP, 80-LQFP package options
- 1 mA/MHz current consumption
- Low cost QuickStart Development System support

ADuC7000 Series: Precision Analog with ARM7 Core

The ARM7 TDMI core is a 32-bit RISC machine. It uses a single 32-bit bus for instructions and data. The TDMI option provides four additional features: a secondary 16-bit Thumb (T) instruction set, debug (D) support, support for long multiplies (M), and the embedded ICE (I) module, containing the breakpoint and watchpoint registers, which allow code to be halted for debugging purposes.

Each ADuC7000 device operates from an accurate (2%) on-chip oscillator and PLL generating an internal 44 MHz clock that is routed through a programmable clock divider from which the MCU operating frequency is generated. Power consumption is 1 mA/MHz.

Up to 128 kB of nonvolatile Flash/EE and 8 kB of SRAM are provided on-chip with both blocks mapped into a single linear array. ARM code can run directly from SRAM at 45 MHz, given that the SRAM is configured as a 32-bit wide memory array. The 80-pin devices support external memory.

On-chip firmware supports in-circuit serial download via the UART and JTAG serial interface ports while nonintrusive emulation is also supported via the JTAG interface.

Part Number	ADC Channel	DACs	Flash/EE (Bytes)	SRAM (Bytes)	GMO (Max)	Comp.	PWM
ADuC7020	5	4	62k	8k	14	✓	
ADuC7021	8	2	62k	8k	13	✓	
ADuC7022	10	–	62k	8k	13	✓	
ADuC7024	10	2	62k	8k	30	✓	✓
ADuC7025	12	–	62k	8k	30	✓	✓
ADuC7026	12	4	62k + ext	8k	40	✓	✓
ADuC7027	16	–	62k + ext	8k	40	✓	✓

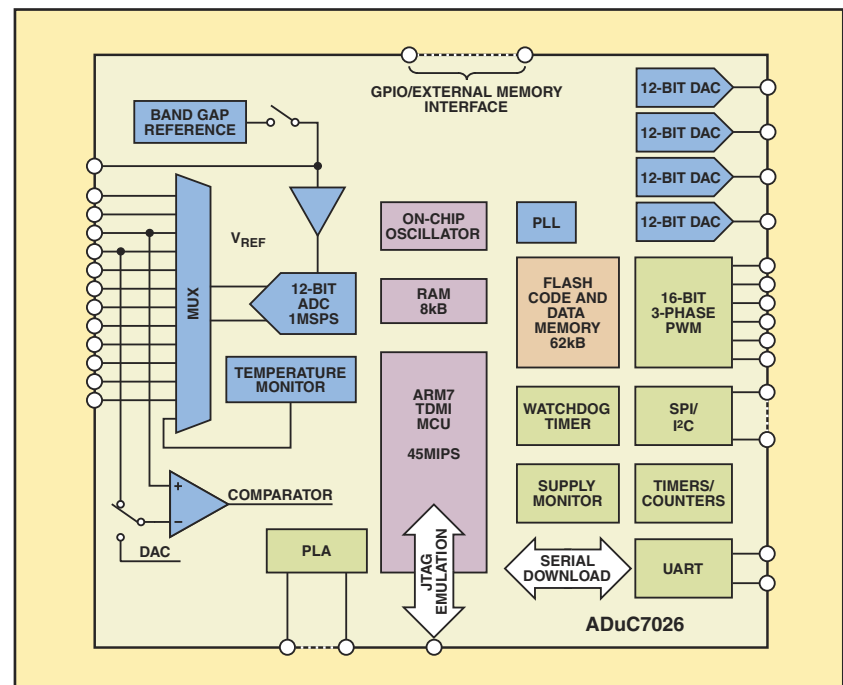


Figure 13. ADuC7206 functional block diagram.

Current Monitoring Design Factors

There are various options with current monitoring designs; the most popular of which include the use of transformers, isolation amplifiers, and more recently, isolated Σ - Δ modulators.

Transformers are used for high power motors. Greater than 3.75 kV isolation is inherent but some signal conditioning circuitry is needed before the signal is applied to a conventional ADC. Advantages include high measurement current and high speed capability. For example, the AD7266, simultaneous-sampling, 12-bit ADC samples up to 2 MSPS, allowing for a very fast loop update rate. Transformers are relatively larger and such systems tend to be costlier. Isolation amplifiers can also be used to bridge the high voltage barrier. They do provide flexibility but typically require extra support circuitry and are not high accuracy. One of the most prevalent solutions is the use of isolated ADC modulators, such as the AD7400 or AD7401. They are designed specifically for current monitoring. They interface directly to current shunts while providing the greatest accuracy, least drift, and need the least amount of support circuitry.

Modulators need postprocessing, either in an FPGA or DSP to convert the high speed serial data to parallel data-words. A popular solution is to use a sinc3 filter which is shown below in Figure 15. It's standard Σ - Δ converter design practice to use a filter with a higher order than the modulator which is 2nd-order for the AD7400. This is to ensure that the filter rolls off the noise faster than the modulator bandwidth profile. Such a filter is used to test the AD7400 devices, for the data sheet-guaranteed specifications at the factory. The postprocessing filter also provides increased noise immunity over conventional SAR solutions in an environment where there is constant switching of large voltages. However, a full sinc3 implementation may be slow for fault protection. Quite often a separate comparator circuit is used to monitor current to protect the IGBT drivers. Alternatively, the use of a shorter filter, i.e. using a lower decimation rate, will give a faster response but with less resolution, and this can be easily done as part of the main sinc3 filter.

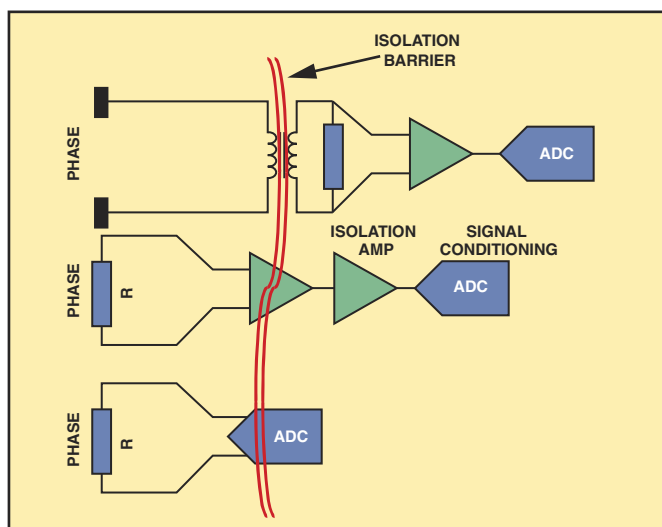


Figure 14. Three common methods of isolation.

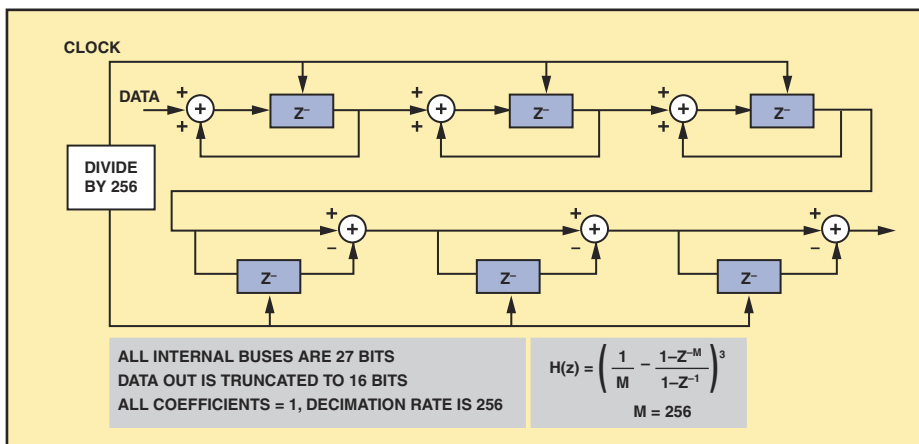


Figure 15. Sinc3 filter diagram.

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